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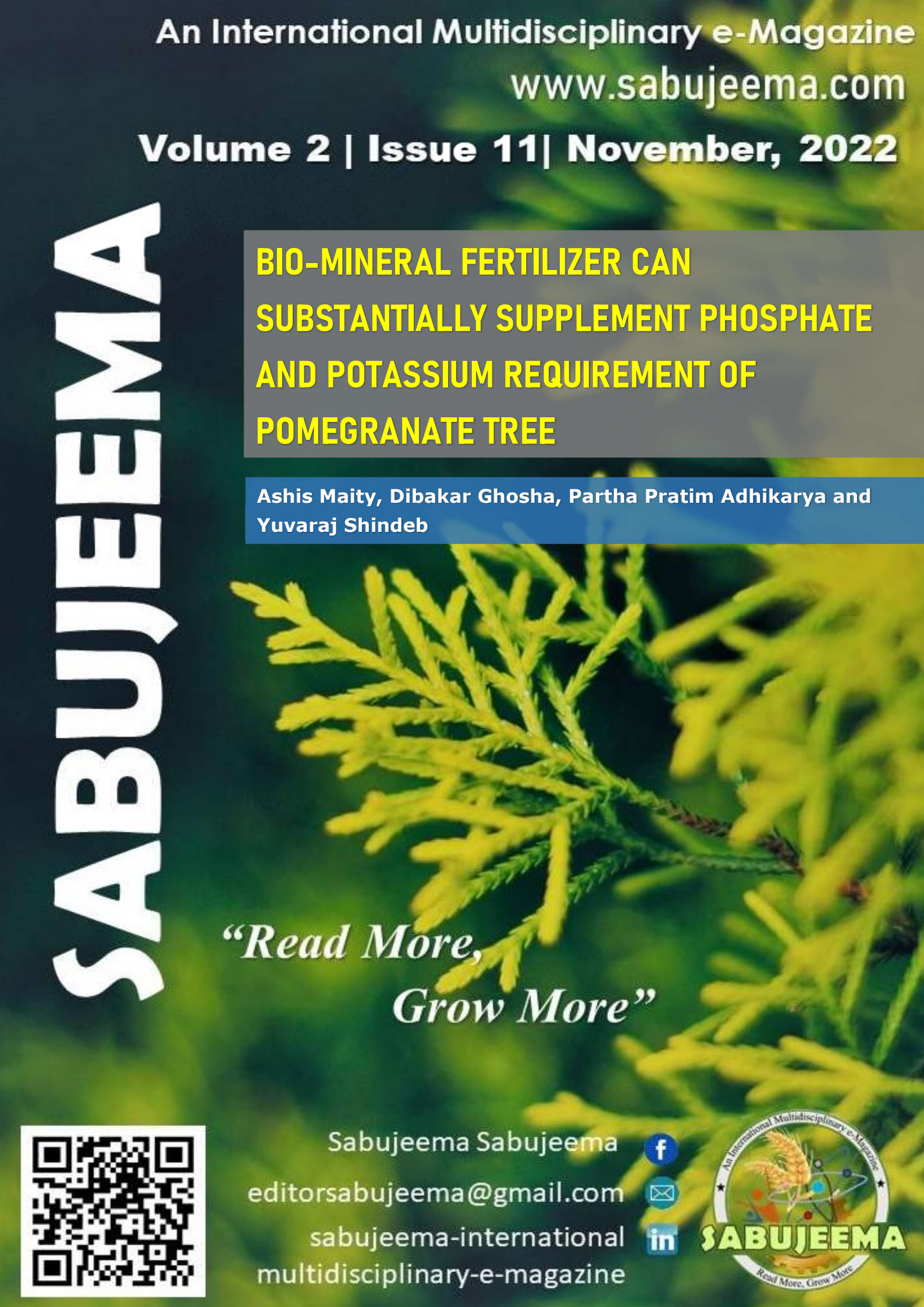

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BIO-MINERAL FERTILIZER CAN SUBSTANTIALLY SUPPLEMENT PHOSPHATE AND POTASSIUM REQUIREMENT OF POMEGRANATE TREE

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ABSTRACT

More reliance on large-scale use of chemical fertilizers as means of increasing productivity of pomegranate over the period has not only caused environmental pollution and raised food safety issues but also raised the cost of cultivation. In order to safeguard the environment and also to curtail the cost of cultivation, a novel organic fertilizer so called phosphorus and potassium supplementing bio-mineral fertilizer which is the combination of P and K containing rock powder and solubilizing fungal microorganisms, *Penicillium pinophilum* (MCC0114) has been developed and evaluated its impact on pomegranate orchard for consecutive two years. Application of bio-mineral fertilizer led to improvement soil microbial environment as indicated by higher microbial biomass carbon, dehydrogenase, and phosphatase enzymes activities observed in the inoculated soil. As a result, availability of macro-nutrients particularly N, P and K in the soil got enhanced. This led to increase in economic fruit yield with perceptible improvement in fruit quality attributes viz. fruit size, aril percent, 100 arils test weight, ascorbic acid (vitamin C), total phenol and anthocyanin concentration in fruit. The highest fruit yield was obtained with application of biomineral fertilizer at the rate of 150 g tree^{-1} (fruit yield increased by 73.97% over control) which was equivalent to the yield obtained with the recommended dose of P and K chemical fertilizers. This biomineral technology is completely environment friendly and has higher benefit-cost ratio of 1.85:1 as against benefit-cost ratio of 1.41:1 obtained with chemical phosphatic and potassic fertilizers at recommended dose.

Keywords: Natural rock powder, nutrient solubilizer, soil biological health, soil fertility, fruit yield.

INTRODUCTION

Major pomegranate growing areas (Maharashtra, Karnataka, Gujarat, Rajasthan and Andhra Pradesh) are characterized by nutrient deficient, shallow gravelly soil with high phosphorus (P) and potassium (K) fixing capacity owing to its inherent mineralogical makeup. Chemical phosphatic and potassic fertilizers are generally applied to restock removed minerals with harvest and to optimize yield. When relatively soluble phosphatic fertilizer is applied to the soil, it

easily gets transformed into insoluble complexes of calcium (Ca), aluminium (Al) and iron (Fe) as well as gets fixed in crystalline and amorphous aluminium silicate. Similar is the case with potassic fertilizers which also get fixed within the soil having predominant 2:1 type expanding clay minerals into insoluble form after its application. Consequently, to achieve optimum crop yield, soluble phosphatic and potassic fertilizers are applied at higher rates. This practice of applying phosphatic and potassic fertilizers at higher rate has contributed to the large reserve of P and K minerals in insoluble forms and hence unavailable form to the pomegranate tree in the orchard soil. In the long-term biological–geological co-evolution, the life activities of surface microorganisms play an important role in a series of surface geochemical processes, such as rock weathering, soil formation and evolution, which directly or indirectly affect the growth of various soil organisms, including the massive formation of terrestrial vegetation.

It can be said that the growth of surface plants depends to a large extent on the mineral nutrients released by soil microbial–mineral interactions. The natural breakdown of many minerals due to microbial metabolic activities, combined with abiotic factors innate to a given ecosystem provide sustenance to plant growth. Thus, enhancing the mineral weathering potential of many microbial groups with external stimuli in the form of mineral ores (rock phosphate, feldspar etc.) have been reported to exert extremely positive effect on soil health and hence fertility- an approach to protect the environment from being polluted further. The composition of Rock Powder fertilizers develops microhabitats that differ in mineral composition and size. Different minerals are colonized by distinct microbial communities and preferential colonization of minerals containing nutrients provides “hotspots” of activity. Applying different combinations of mineral rich Rock Powder to soil influences bacterial communities in bulk soil. The role of minerals is thus two-fold; to provide nutrients for the plant, and to provide opportunities for microbial health within the soil, making them resilient and resistant to attack.

BIOMINERAL FERTILIZER AND ITS IMPORTANCE

The development of a fertilizer that contains both minerals and microbes (a biomineral fertilizer) benefits both the plant and the environment is known as bio-mineral fertilizer. So, we have seen plenty of literatures showing the cognizable effect of conjunctive use of P and K solubilizing microorganism and rock powder such as rock phosphate, feldspar/micas in producing yield which were at par with that obtained from the use of chemical phosphatic and potassic fertilizer at recommended dose. But such technology did not receive much acceptance by the farming community as arranging and using rock materials with solubilizing P and K bio-fertilizers were troubleshooting. So, the concept of integrating insoluble rock materials into a formulation of P and K solubilizing microorganism gave rise to the development of phosphate and potassium supplementing bio-mineral fertilizer.

Biology is efficient when it comes to plants and animals expending energy because having it and getting it are central to survival. When fertilized, plants don’t need to spend as much energy to get nutrients, so they don’t grow as extensive a root system or produce as many exudates. This translates into fewer mycorrhizal fungi and beneficial bacteria in the rhizosphere. The net result is a decline in

the nutrient exchange, mineral uptake, and phytochemical production vital to plant health and defense against pathogens. In a comparison of wheat grown under organic and conventional practices in southeastern Australia it was found that conventional fertilization not only increased crop yields and phosphorus concentrations, it also reduced zinc uptake. Providing a biomineral fertilizer to the plant provides both the nutrients and biology to deliver these nutrients to the plant. When soil microbes known to deliver P and K to plants are added to soil, mineral uptake increases. Additionally, microbial metabolites stimulate plants to produce phytochemicals with antibacterial and antifungal properties to suppress pathogens and promote plant health. It is possible that microbial partnerships hold tremendous potential to reduce, or even replace, pesticides and fertilizers to sustain intensive agriculture.

The increase in root and microbial activity in soil leads to an overall increase in soil organic carbon which has an impact on both soil functions and ecosystem services. Dead microbes within the soil can account for up to 80% of the organic matter in soil, and this alone has a significant impact.

The important improvements in soil and ecosystem function that take place owing to application of bio-mineral fertilizer are as follows.

- Soil organic carbon is largely composed of organic carbon, nitrogen (90-95% of soil N), phosphorus (40% of soil P) and sulfur (90% of soil S). As the nutrients are re-cycled internally over time through plant uptake and residue deposition, microbial decomposition, and SOM formation, effective soil carbon development has the potential to reduce the need for additional N and P fertilization. At the same time, rock powders (potassium feldspar, micas etc.) will supply the potassium (K), released by microbial activity to greatly reduce the reliance on, and to eventually replace, chemical fertilizers.
- Increases in soil carbon improves the soil's cation exchange capacity - the capacity to store nutrients in soil. An increase in carbon will reduce the leaching of soluble nutrients out of the root zone and into surface water.
- Plant available soil water also get enhanced between 1-10 gram for every 1 gram of soil organic matter. The ability of organic matter to hold water is due to both

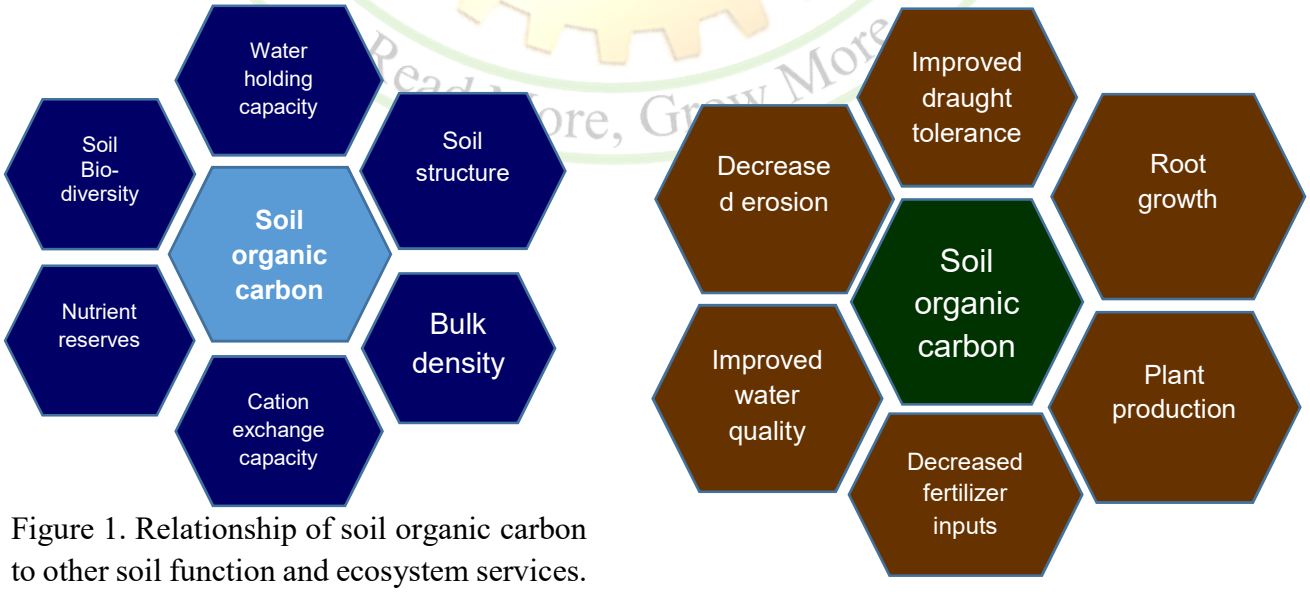


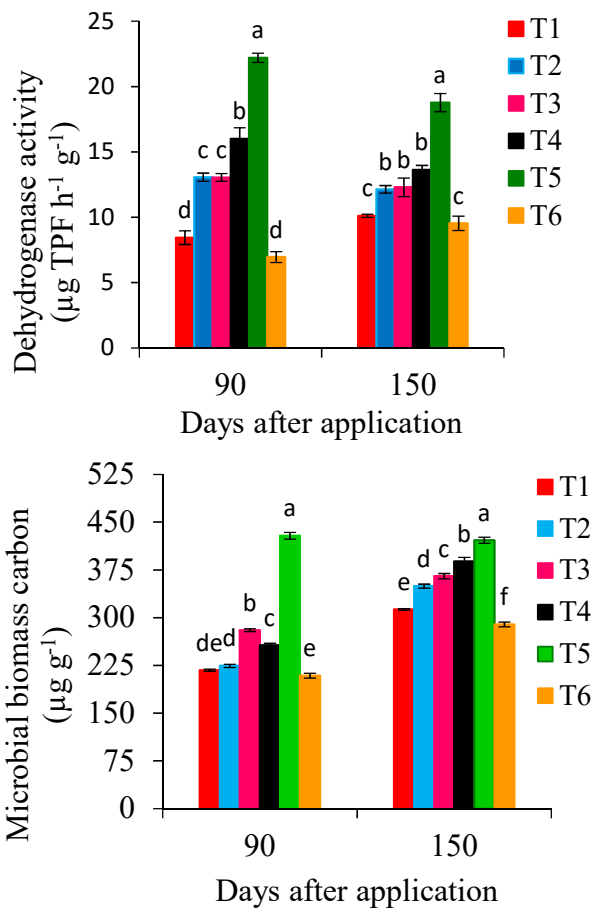
Figure 1. Relationship of soil organic carbon to other soil function and ecosystem services.

its properties and improvement in soil structure. Soil organic carbon enhances soil structure and aggregation, leading to improved infiltration, aeration and root growth, and less compaction and crusting, all of which help in reducing erosion. Certain fungi have also been associated with improved drought tolerance.

- In addition to managing Earth's soils for food production, there is an increasing need for managing the soil for environmental regulation and Earth system functioning. Building and improving the soil natural capital is an important aim contributing to soil resilience and maintaining balance in the provision of ecosystem services.

CASE STUDIES OF BIOMINERAL FERTILIZER USE IN POMEGRANATE ORCHARD

A phosphate and potassium supplementing bio-mineral fertilizer was developed by mixing the spores of phosphate and potassium solubilizing fungi *Penicillium pinophilum* (MCC0114) with mineral mixture comprising of potassium feldspar and rock phosphate powder (2:1). The said bio-mineral fertilizer was applied to the rhizosphere soil of pomegranate orchard and the results showed the positive influence of bio-mineral fertilizer on soil dehydrogenase, acid and alkaline phosphatase and microbial biomass carbon content over the period (Figure 2). From the below presented figure it was clear that improvement in soil enzymes activities and microbial biomass carbon was higher with bio-mineral fertilizer than with same fungal (*Penicillium pinophilum*) based P and K solubilizing bio-formulation. It was also observed that soil enzymes activities and microbial biomass carbon content increased with the increasing dose of bio-mineral fertilizer and reached to highest level at the highest dose of bio-mineral fertilizer application (i.e. at the rate of 600 g tree^{-1}). While with application of chemical phosphatic and potassic fertilizers at recommended dose neither soil enzymes activities nor microbial biomass carbon content got improved rather decrease in microbial biomass content was noticed. This indicate that the application of bio-mineral fertilizer not only enhance metabolically active microbial population in the pomegranate rhizosphere but also their activity in mineralizing organic nutrients particularly P which was reflected through noticeable improvement in alkaline and acid phosphatase enzymes activities.



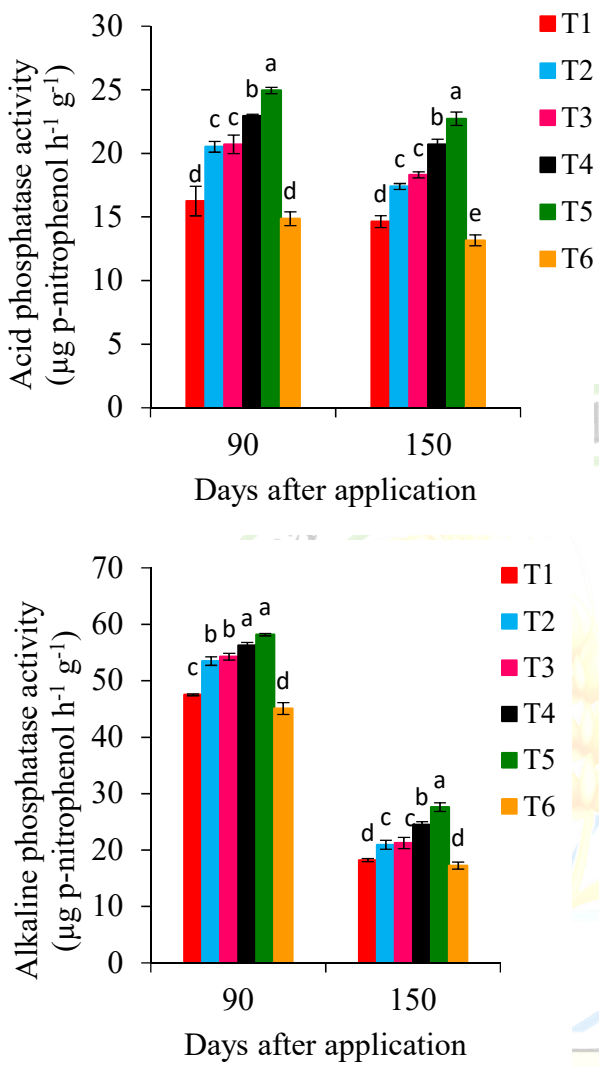


Figure 2. Effect of bio-mineral fertilizer on soil enzymes activities and microbial biomass carbon content. T1–Non-inoculated soil; T2–Soil inoculated with *Penicillium pinophilum* based bio-formulation at the rate of 20 g tree^{-1}; T3–Soil application of bio-mineral fertilizer at the rate of 150 g tree^{-1}; T4–Soil application of bio-mineral fertilizer at the rate of 300 g tree^{-1}; T5–Soil application of bio-mineral fertilizer at the rate of 600 g tree^{-1}; T6–Application of phosphatic and potassic chemical fertilizer at 100% of recommended dose (RD).

EFFECT OF BIO-MINERAL FERTILIZER ON SOIL AVAILABLE NUTRIENT CONTENT

Application of bio-mineral fertilizer notably enhanced available N, P, and K content in the soil (Figure 3) at physiologically important stage i.e. at fruit setting and development stage. The highest available N content was recorded with the application of bio-mineral fertilizer at a higher dose (i.e. 600 g tree^{-1}). This indicates higher order organic N mineralization recorded with higher dose of bio-mineral fertilizer application. This was supported by the fact of higher microbial biomass carbon noted in this treatment. While, the soil treated with potassium solubilizing bio-formulation and bio-mineral fertilizer recorded the highest available P content in soil, which was at par with that recorded in soil fertilized with P and K chemical fertilizers at recommended dose. Although, bio-mineral fertilizer application at the rate of 150 g tree^{-1} significantly improved available soil K as compared to treatment receiving only potassium solubilizing bio-formulation and control but it was lower than that noted with the recommended dose of P and K chemical fertilizers application. We could not find any significant effect of bio-mineral fertilizer application on the available S content of soil.

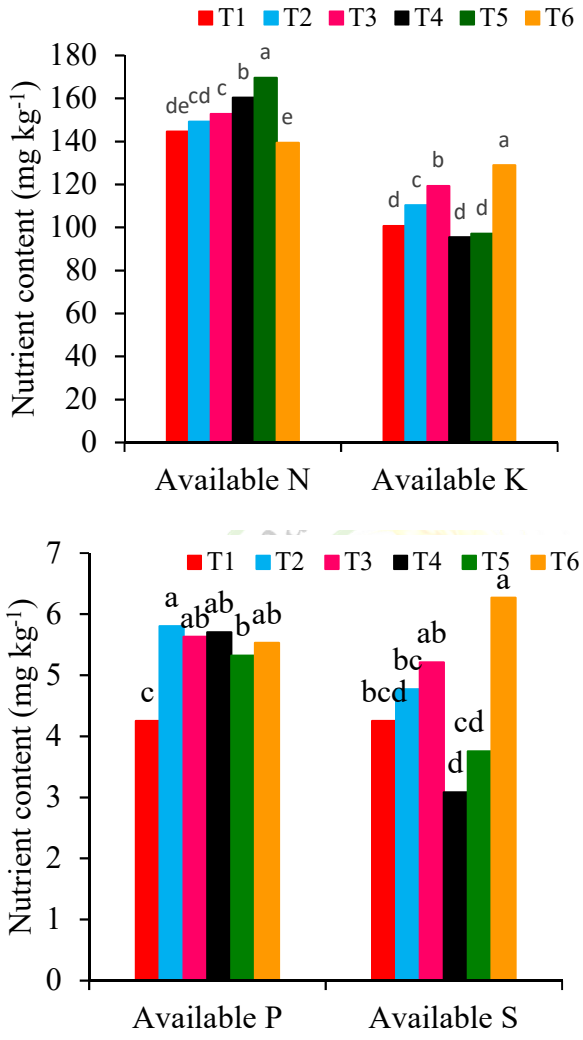


Figure 2. Effect of bio-mineral fertilizer application on soil available nutrient content at fruit setting and development stage of pomegranate. T1–Non-inoculated soil; T2–Soil inoculated with *Penicillium pinophilum* based bio-formulation at the rate of 20 g tree^{-1}; T3–Soil application of bio-mineral fertilizer at the rate of 150 g tree^{-1}; T4–Soil application of bio-mineral fertilizer at the rate of 300 g tree^{-1}; T5–Soil application of bio-mineral fertilizer at the rate of 600 g tree^{-1}; T6–Application of phosphatic and potassic chemical fertilizer at 100% of recommended dose (RD).

Impact of bio-mineral fertilizer application on flowering behavior, fruit setting and fruit yield

Soil application of *Penicillium pinophilum* based potassium solubilizing bio-formulation and bio-mineral fertilizer increased number of male and bi-sexual flowers in pomegranate trees. However, the response of bio-mineral fertilizer towards flowering behavior of pomegranate tree was far superior than potassium solubilizing bio-formulation and also the application of phosphatic and potassic fertilizers at recommended dose.

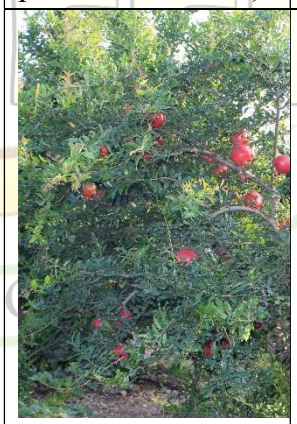
	
T1-Control fruit bearing trees (without any phosphatic and potassic fertilizers)	T2- Response of potassium solubilizing bio-formulation.
	
T3-Response of P and K supplementing bio-mineral fertilizer	T6-Response of phosphatic and potassic fertilizers at recommended dose.

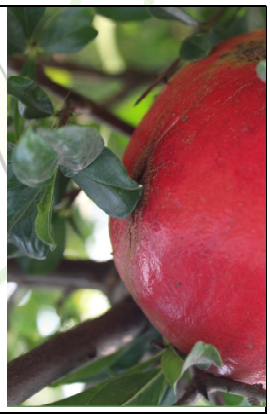
Figure 4. Effect of *P. pinophilum* based potassium solubilizing bio-formulation and P and K supplementing bio-mineral fertilizers on fruit bearing, fruit size and fruit yield.

As a consequence, both the potassium solubilizing bio-formulation and bio-mineral fertilizer resulted cognizable improvement in economic fruit yield (Table 1, Figure 4). Here, also the magnitude of increase in yield was higher with the application of bio-mineral fertilizer (73.97%) than with potassium solubilizing bio-formulation application (34.19%). The fruit yield obtained with P and K supplementing bio-mineral fertilizer was par with that recorded with the application of phosphatic and potassic fertilizers at recommended dose. And moreover, application of bio-mineral fertilizer yielded higher proportion of exportable grade (fruit weighing more than 250 g) fruit than potassium solubilizing bio-formulation and phosphatic and potassic fertilizer application at recommended dose. So, from the observed fruit yield data, it can be inferred that *P. pinophilum* based bio-mineral fertilizer can totally replace the phosphatic and potassic fertilizer requirement without compromising economic fruit yield in pomegranate.

Table 1. Influence of bio-mineral fertilizer on flowering behavior and fruit yield of pomegranate

Treatment	Flower No.		Fruit set (%)	Fruit yield (kg tree^{-1})	Percent fruit > 250 g
	Male	Bisexual			
T1: Control	252^{d}	152^{c}	51.38^{bc}	8.95^{d}	19.07^{e}
T2: K solubilizing bio-formulation @ 20 g tree^{-1}	297^{bc}	174^{b}	52.63^{ab}	12.01^{c}	22.49^{d}
T3–Bio-organic fertilizer @ 150 g tree^{-1}	331^{a}	209^{a}	54.93^{a}	15.57^{a}	27.90^{a}
T6: Recommended dose of P and K through chemical fertilizers	233^{d}	120^{d}	46.27^{d}	15.62^{a}	24.14^{cd}
Tukey's HSDα0.05	30	18	2.45	0.78	1.96

Fruit size observed with recommended dose of phosphatic and potassic fertilizers



Fruit size and colour recoded with P and K supplementing bio-mineral fertilizer

Figure 4. Visual effect of P and K supplementing bio-mineral fertilizer on pomegranate fruit size and color.

Further, bio-mineral fertilizer application at the rate of 150 g tree^{-1} led to the production of 27.90% fruit weighing more than 250 g, while it was only 24.14% and 19.07% recorded in treatments receiving the recommended dose of P and K chemical fertilization and control (without P and K fertilization), respectively. Besides, it also improved internal quality of fruit such as aril percent, hundred arils test weight, ascorbic acid (vitamin C), total phenol and anthocyanin content of fruit.

Recommended practice to be followed

Phosphate and potassium supplementing *P. pinophilum* based bio-mineral fertilizer is recommended to be applied at the rate of 150 g tree-1 (i.e. 111 kg ha^{-1} assuming 740 trees per ha) in two splits, once during rest period of the crop and another during release of stress or at the time of first irrigation. This biomineral fertilizer is required to be inoculated with well decomposed, pulverized cow-dung manure in 3:10 ratio and incubated for 10-15 days with moisture content at field capacity and periodic turnings at 3 days interval for increasing microbial load of bio-mineral fertilizer. This bio-mineral inoculated cow-dung manure can be applied to the pomegranate root zone below the dripper position at the rate of 500 g tree^{-1} followed by mixing and covering with soil and light irrigation. For getting good response, this bio-mineral fertilizer needs to be applied either early in the morning or late in the evening.

CONCLUSION

Techno-feasibility analysis revealed that application of bio-mineral fertilizer at the rate of 150 g tree^{-1} gave rise to higher benefit-cost ratio of 1.85:1 which were even higher than that management practices receiving P and K chemical fertilizers at the recommended dose (benefit-cost ratio 1.41:1). This ensures the economic viability of the technology for large scale adoption by the pomegranate farmers. This bio-mineral fertilizer technology is completely environment friendly and has potential to drastically reduce the usage of chemicals fertilizers particularly phosphatic and potassic fertilizers in pomegranate orchards and sequester the elevated CO_2 in the atmosphere.

This P and K supplementing bio-mineral fertilizer is an important P and K sources for utilizing in residue free organic pomegranate production system.